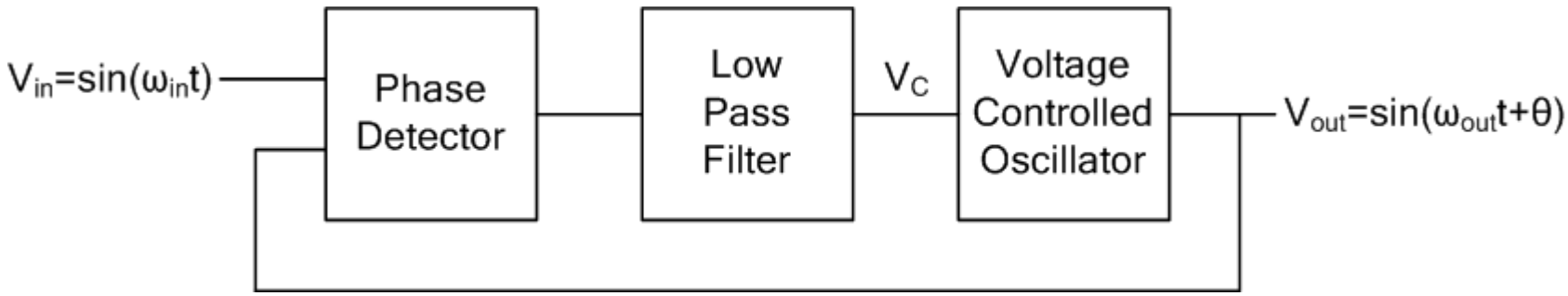
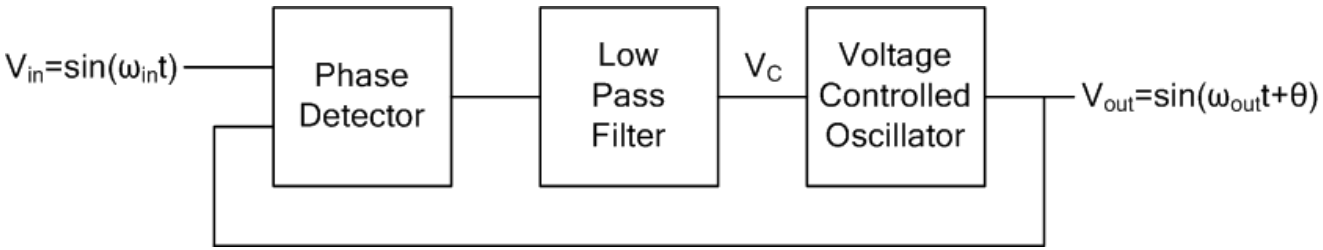
Lect. 25: PLL

PLL (Phase-Locked Loop): A closed-loop feedback system that synchronizes output signal with input signal in frequency and phase



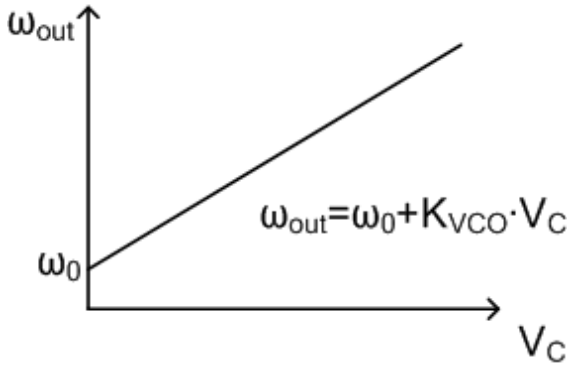
➔Frequency locking of input and output ($\omega_{in}=\omega_{out}$) with constant phase difference (θ)

Lect. 25: PLL



VCO (Voltage Controlled Oscillator): Frequency-tunable oscillator

➔ Output frequency is a function of control voltage (V_C)



Lect. 25: PLL

Electronic Oscillators (Chap. 13 in Razavi 2nd Edition)

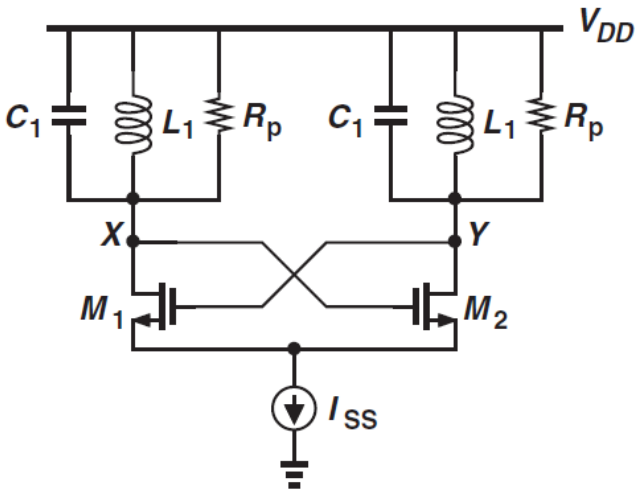
- Crystal oscillator (Razavi 13.6): Piezoelectricity

Very accurate and stable oscillation frequency

But limited frequency range (typical up to tens of MHz)

Used as a master clock in many electronic systems

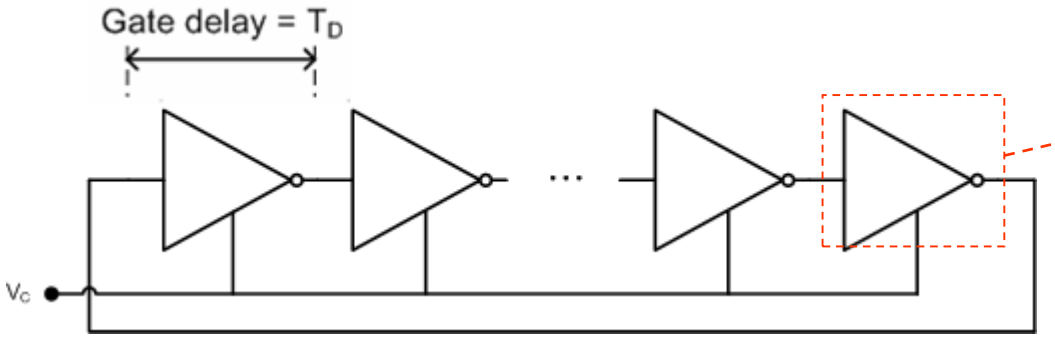
- LC oscillators (Razavi 13.3)

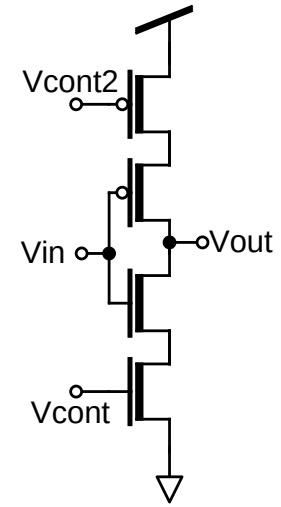


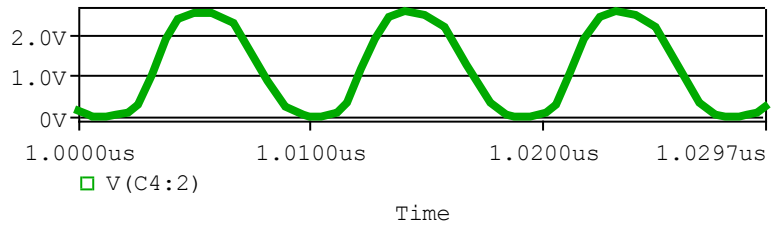
Lect. 25: PLL

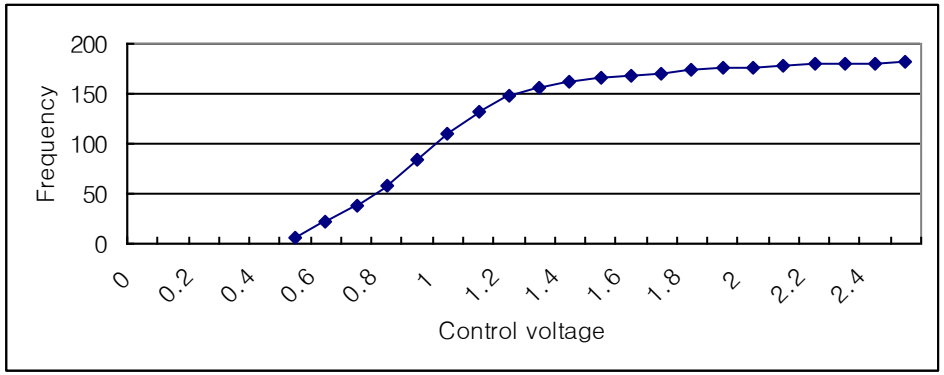
- Ring-oscillator: Odd-stage chain of inverters

Voltage control of oscillation frequency



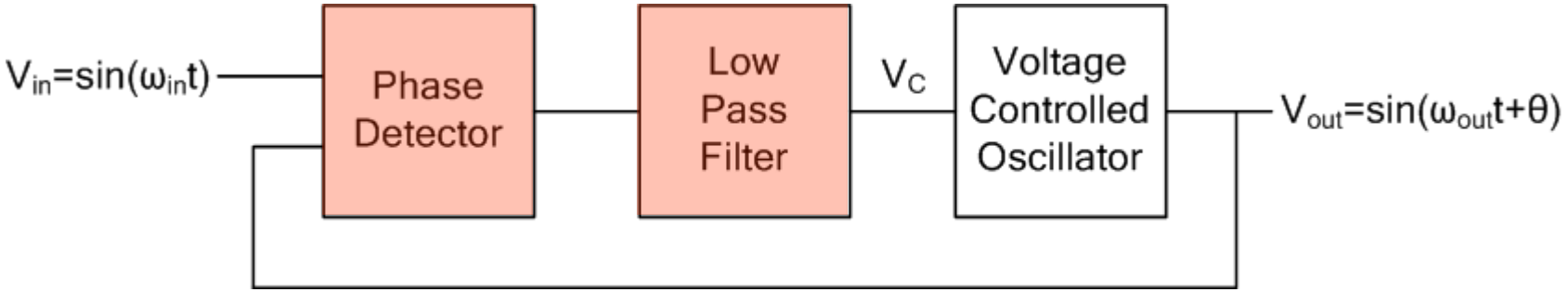






$$T = 2nT_D \qquad f = \frac{1}{T} = \frac{1}{2nT_D}$$

Lect. 25: PLL



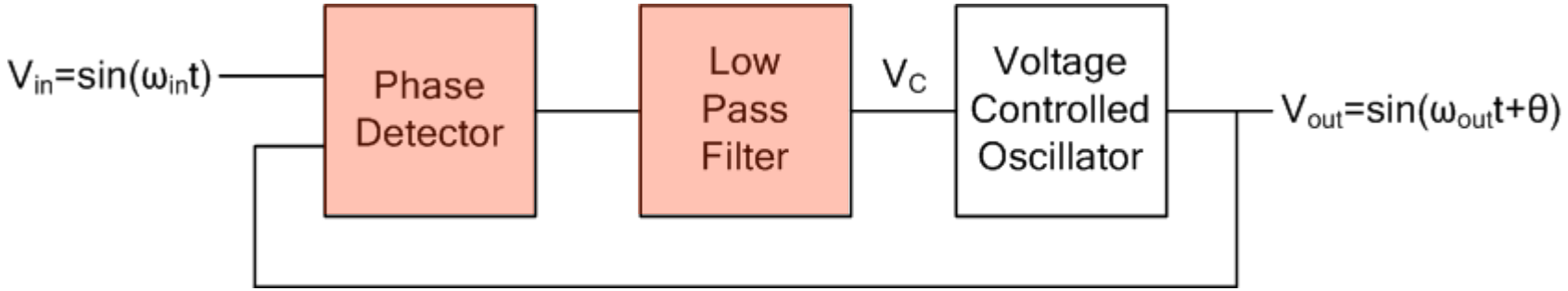
PD (Phase Detector): Compares phases of input and output signal and converts the phase difference to voltage signal

LPF (Low Pass Filter): Takes an average level of PD's output voltage signal

PD can be realized with a multiplier

$$\sin(\omega_{in}t)\sin(\omega_{out}t+\theta) = \frac{1}{2}\{\cos[(\omega_{in}-\omega_{out})t-\theta]-\cos[(\omega_{in}+\omega_{out})t+\theta]\}$$

Lect. 25: PLL

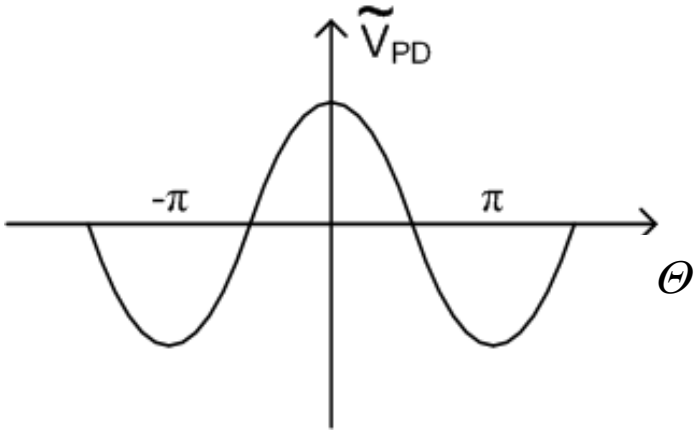


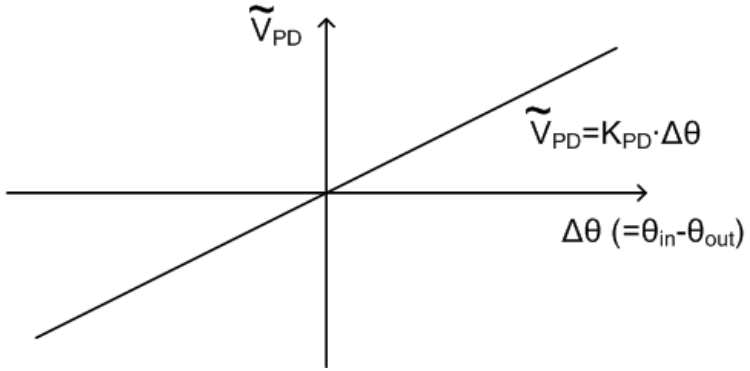
$$\sin(\omega_{in}t)\sin(\omega_{out}t+\theta) = \frac{1}{2}\{\cos[(\omega_{in}-\omega_{out})t-\theta]-\cos[(\omega_{in}+\omega_{out})t+\theta]\}$$

Filtered out by LPF

Assuming $\omega_{in}=\omega_{out}$

Approximately linear for $\theta = -\pi/2$

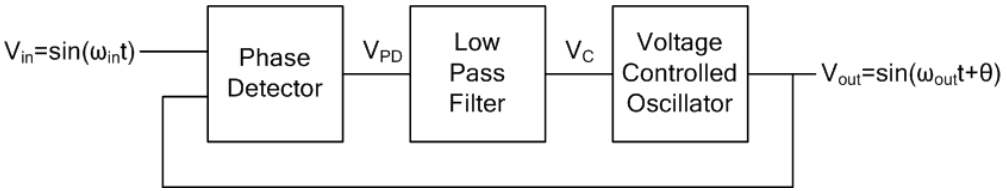




Lect. 25: PLL

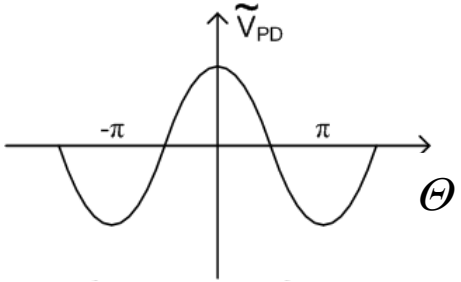
Phase tracking of PLL

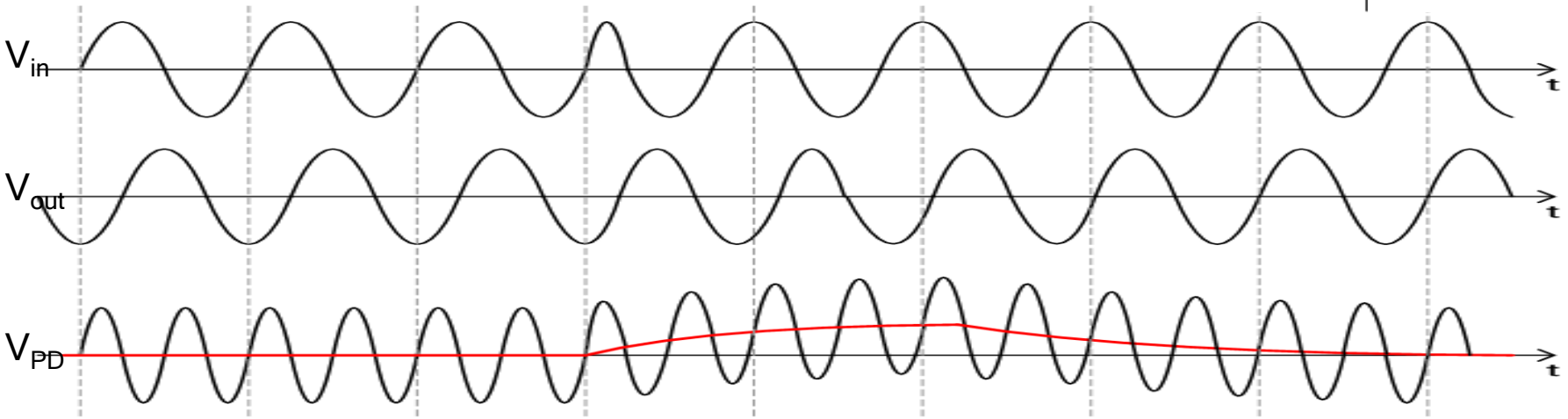
$\omega_{in}=\omega_{out}$



Initially, V_{out} is locked to V_{in}
With $\theta = -\pi/2$

Phase jump in V_{in} here

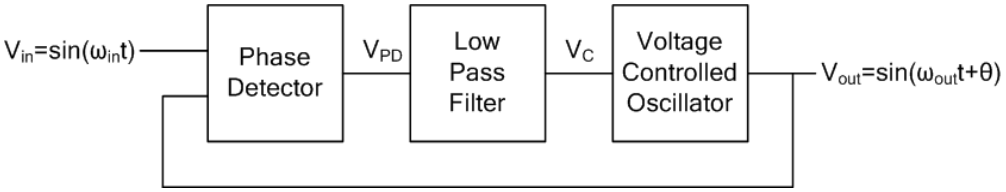




Lect. 25: PLL

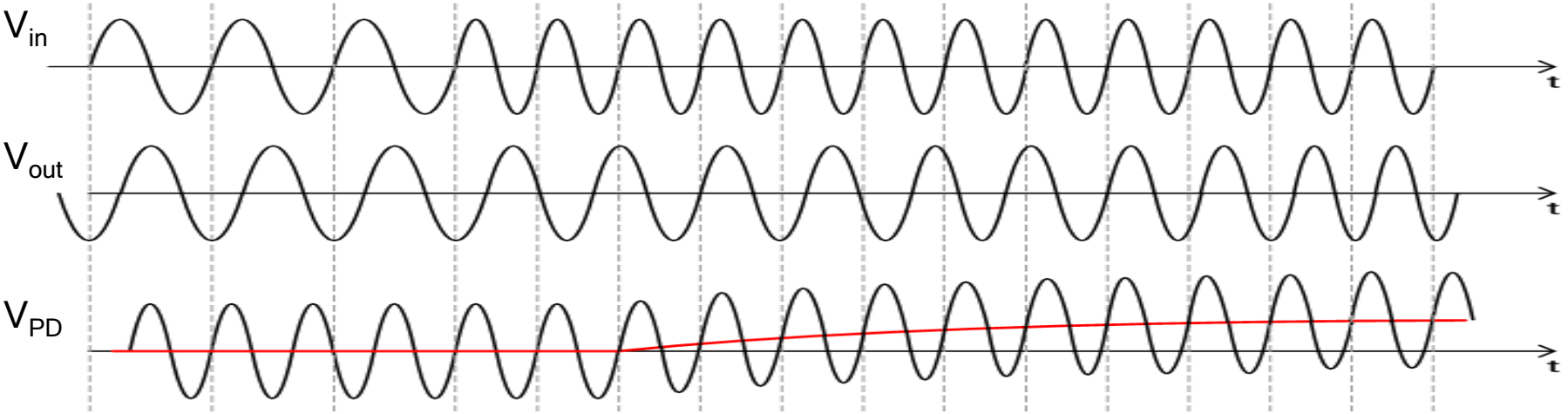
Frequency tracking of PLL

$\omega_{in} \neq \omega_{out}$



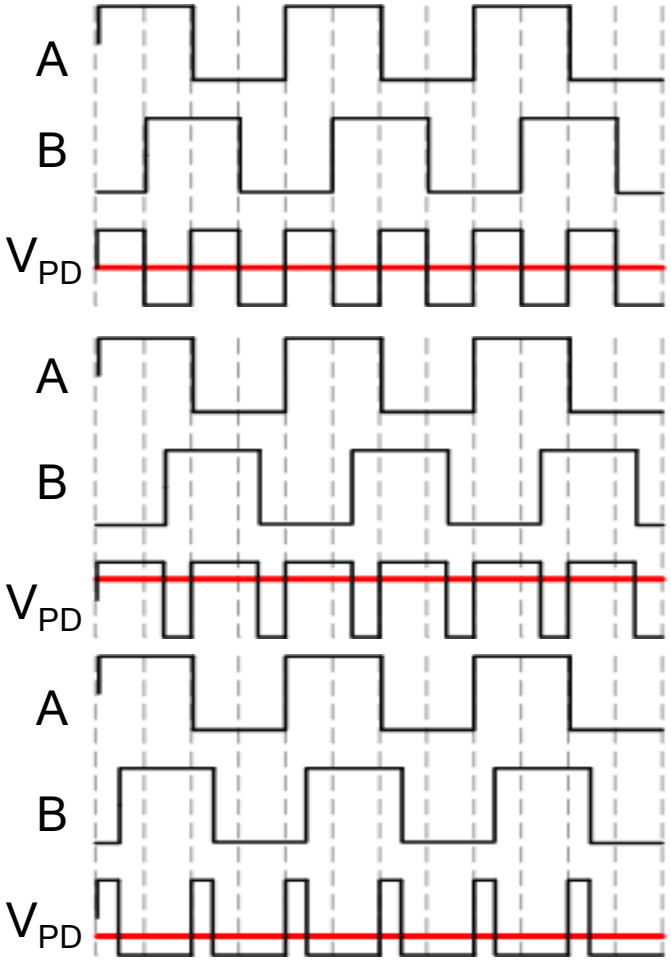
V_{out} is locked to V_{in}
With $\theta = -\pi/2$

Frequency jump in V_{in} here



XOR gate can be used as PD for digital signals

A	B	V_{PD}
0	0	0
0	1	1
1	0	1
1	1	0



Locked
(π/2 phase offset)

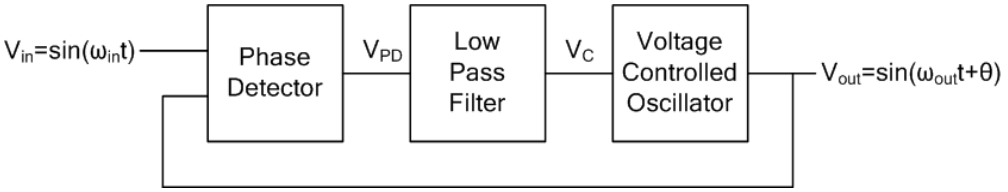
B later than A

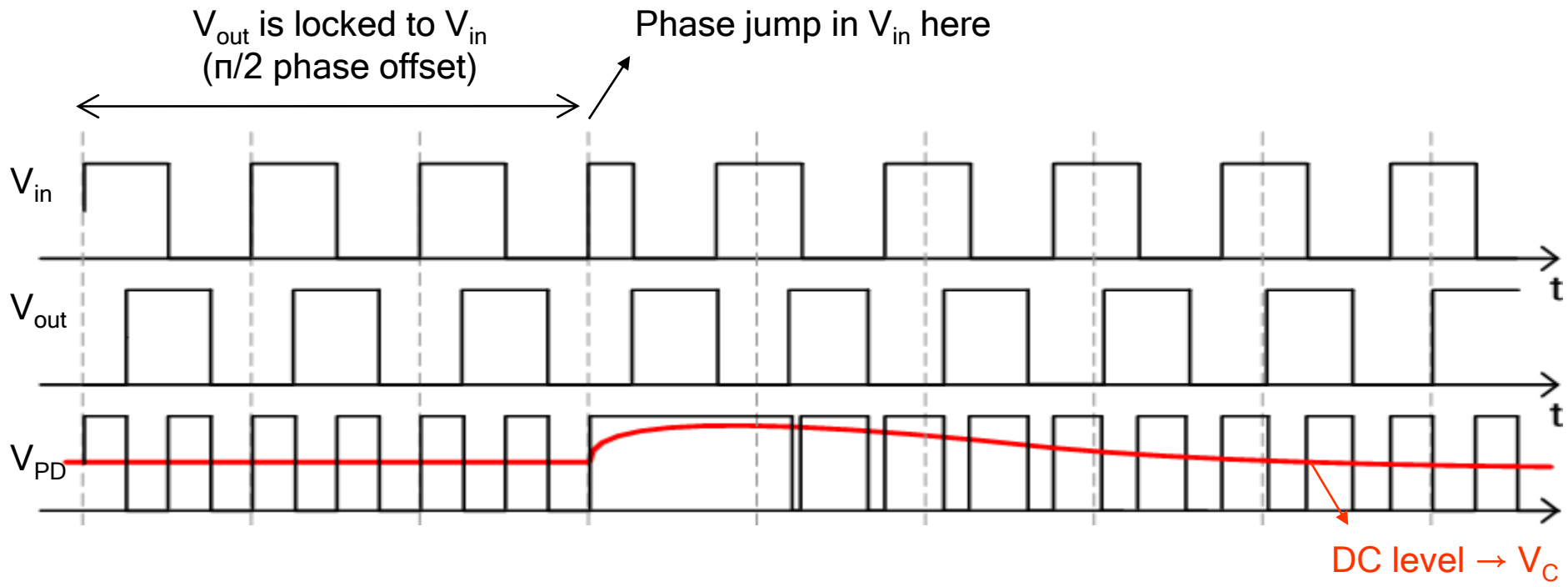
B earlier than A

Lect. 25: PLL

Phase tracking of PLL

$\omega_{in}=\omega_{out}$

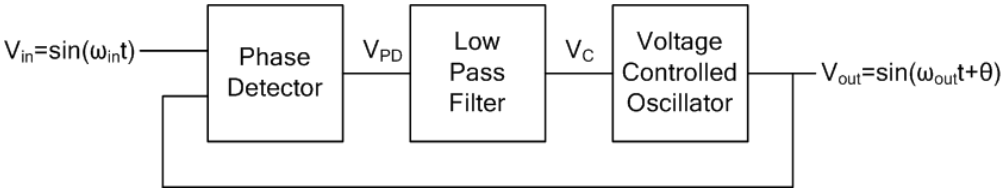


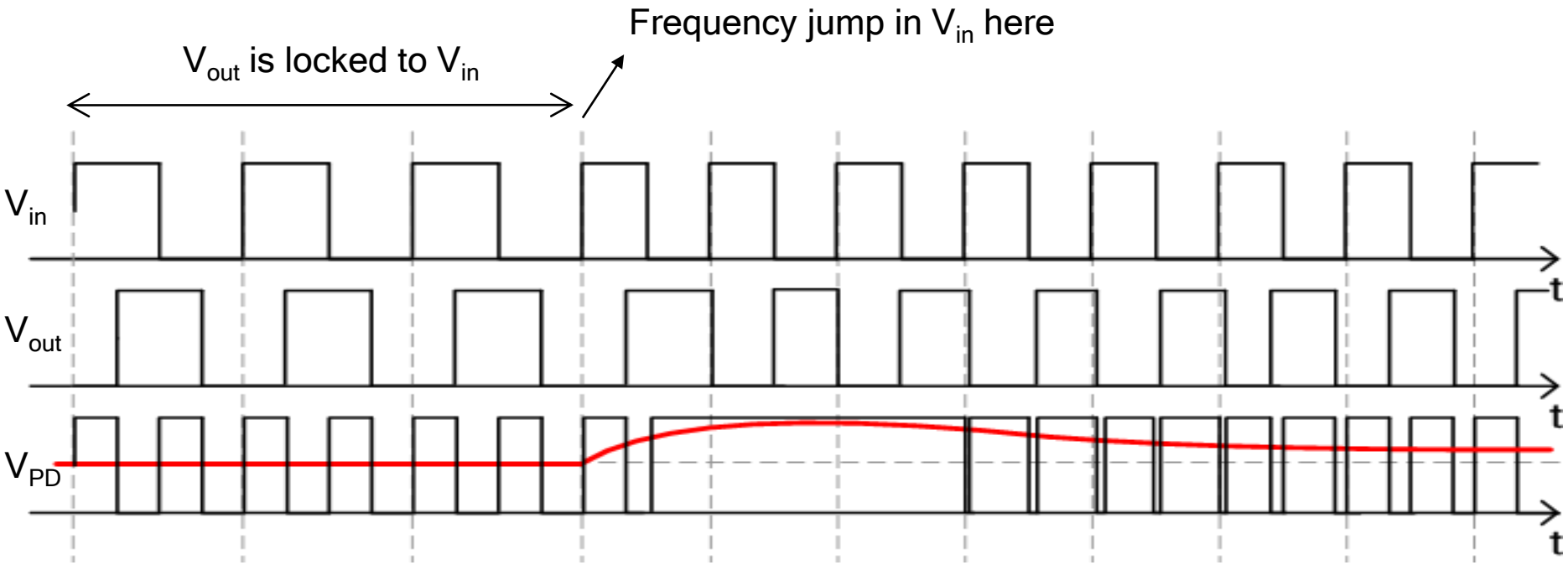


Lect. 25: PLL

Frequency tracking of PLL

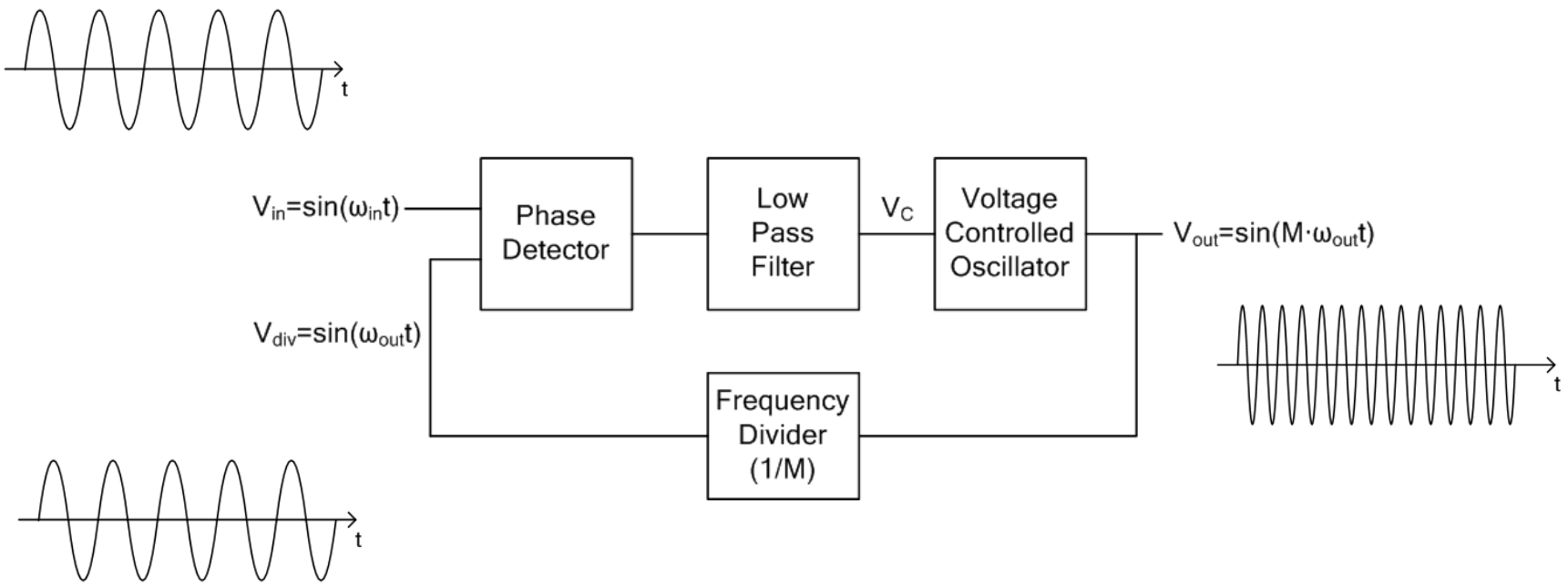
$\omega_{in} \neq \omega_{out}$





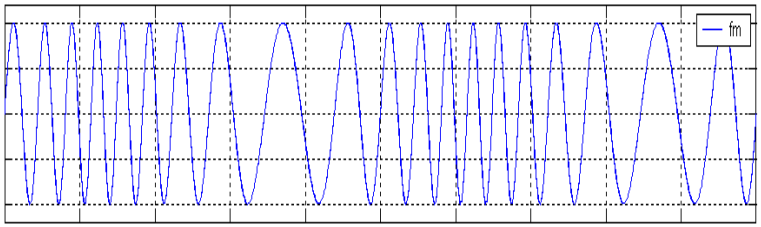
Lect. 25: PLL

Applications of PLL: Frequency Synthesis

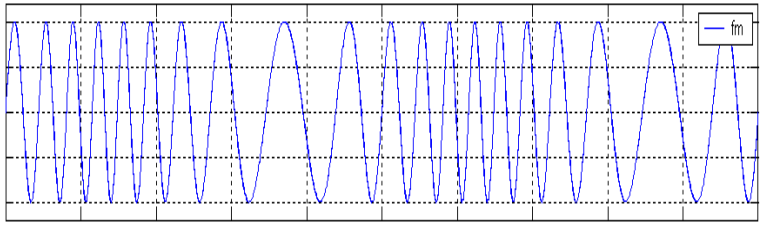


Lect. 25: PLL

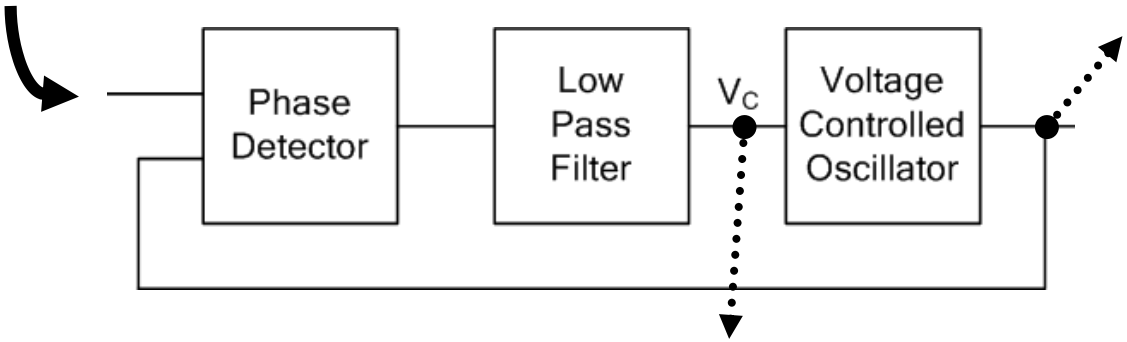
Applications of PLL: Frequency Demodulation

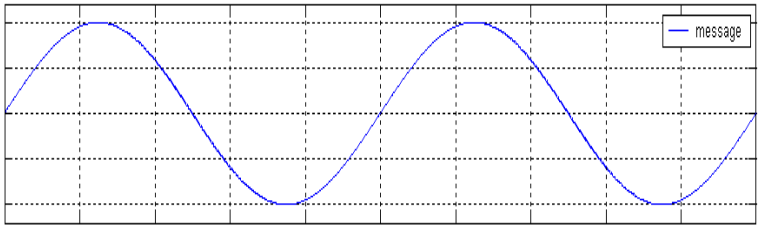


(FM signal)



(PLL output)





(Recovered message)

Lect. 25: PLL

Applications of PLL: Clock signal recovery for digital signals